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(71) Applicant
The Secretary of State for Defence,

(Incorporated in United Kingdom),

Whitehall, London SW1A 2HB

(72) Inventors
Derek Graham Older,
Suresh Kumar

(74) Agent and/or Address for Service
S. R. Sketton, Procurement Executive, Ministry of Defence, Patents 1A4, Room 2014, 19th Floor, Empress State Building, Lillie Road, London SW6 1TR

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(54) Ablative material

(57) An ablative material protective liner for the casing of a solid propellant rocket motor includes (a) a layer of reinforcing fabric having projecting therefrom anchor means associated with the fabric layer and (b) a polymeric matrix, the fabric layer and anchor means being embedded within the matrix. Preferably the anchor means projects perpendicularly from the surface of the fabric and points towards the casing, and takes the form of tufts or loops of thread which may be arranged in rows, spaced between about 7.5 mm and about 15.5 mm apart. The polymer matrix is preferably an elastomer and the fabric is preferably woven from threads which neither melt nor soften at the temperatures to which the ablative material is expected to be exposed, e.g. comprise phenolic based fibres, aramid fibres or carbon fibres.

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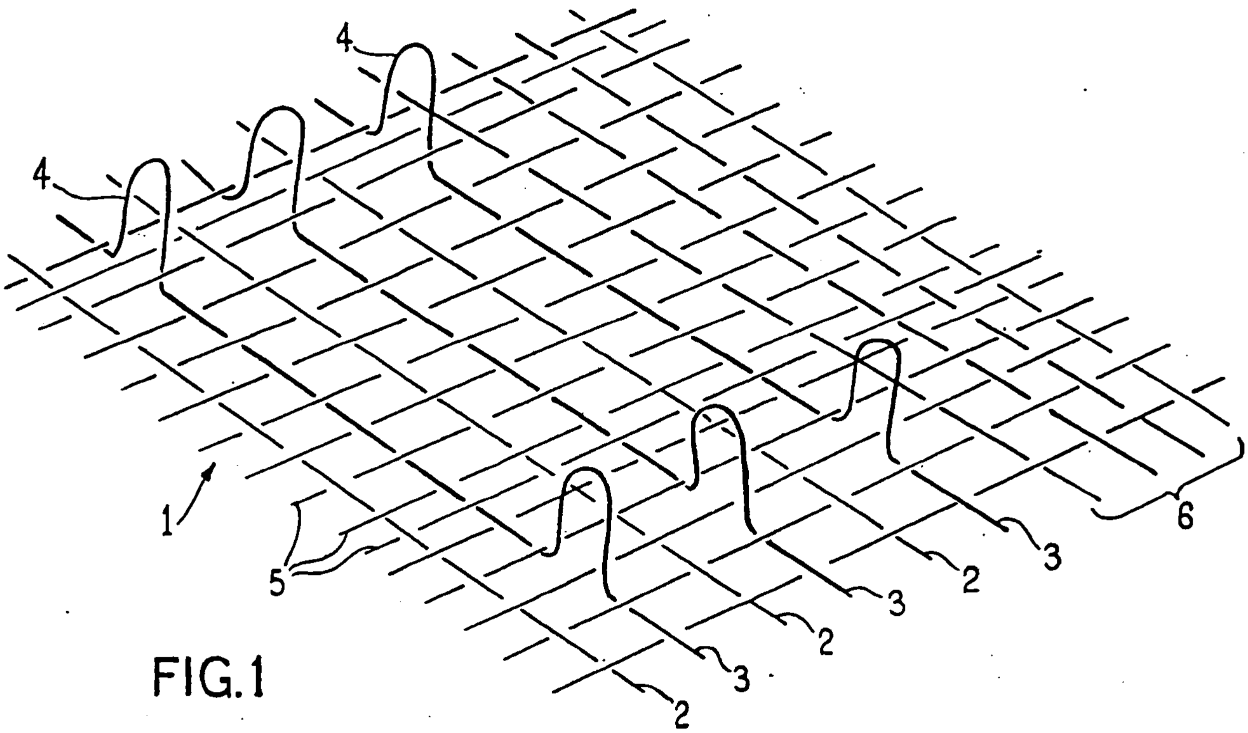

FIG.1

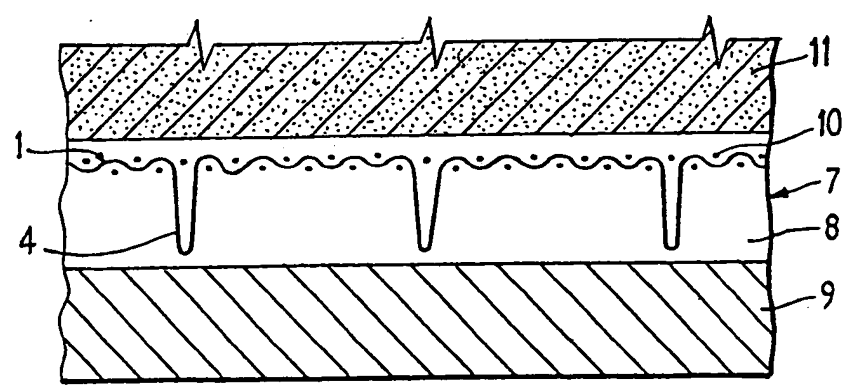

FIG.2

SPECIFICATION

Ablative material

The present invention relates to ablative materials.

Ablation is a process whereby at high temperatures thermal energy is expended by the sacrificial loss of material from a protective shield, applied to a primary structure for which protection from high temperature environments is sought. The materials which comprise such shields are commonly known as ablative materials and typically consist of fibre reinforced composites or composites reinforced with particulate matter. The principle of ablation is typically exploited in certain aerospace applications where it is essential to provide thermal protection for primary structures such as, for example, space re-entry vehicles and solid propellent rocket motors.

The rates at which an ablative material is eroded and at which heat diffuses through it during the process of ablation, the duration of exposure to the environment which causes the process to occur and the thermal conductivity of the material, determine the minimum thickness of material required to provide effective thermal protection to the primary structure to which it is applied. It is therefore desirable to employ an ablative material which has both a low rate of erosion and a low density in order that the amount of ablative material required and in consequence overall weight is kept to a minimum.

According to a first aspect of the present invention an ablative material comprises (a) a layer of woven reinforcing fabric having a first surface and a second surface, the second surface having projecting therefrom anchor means associated with the fabric layer, and (b) a polymeric matrix, the fabric layer and the anchor means being embedded within the matrix. Preferably the anchor means projects substantially perpendicularly from the second surface of the fabric.

Preferably the reinforcing fabric comprises a loosely woven plain weave fabric with a weft to warp ratio of 1:1 and about 9-11 threads per inch (about 3-5 threads per cm).

The anchor means may be any suitable arrangement of short discontinuous or continuous threads which stand proud of the fabric surface for example, tufts or loops, and these may be incorporated into the woven fabric either during the weaving process or added to the fabric after weaving in separate operations, by any conventional means employed in the textiles or carpet-making arts. It is preferred that the anchor means takes the form of loops of thread. The extent to which the loops pr ject beyond the surface of the fabric is determined by the required thickness of th ablative material and it is therefore desirable that the size of the l ops approximately corresponds to the thickness of the ablative material. Preferably the loops are incorporated in the fabric during the process of weaving and it is preferred that they are provided in alternative warp threads. The loops may be located at random in the fabric or they may be arranged in specific patterns but it is preferred that th y are arranged in rows, across the weft. Th spacing between the rows may be any desired interval.

Suitably, the rows of loops are located at intervals of between about 0.3 inches (7.5 mm) and about 0.6 inches (15.5 mm).

Preferably, the fabric comprises threads which are sufficiently flexible to permit the formation of loops without cracking or breaking either during the formation of the loops or subsequently. In addition it is preferred that the fabric comprises threads which neither soften nor melt at the temperatures to which the ablative material is expected to be exposed. Examples of suitable threads include phenolic based fibres, aramid fibres, and carbon fibres. Certain other fibres, for example cellulosic fibres and polyacrylonitrile fibres may also be suitable. It is believed that such fibres produce carbonaceous fibrous residues under non-oxidising ablative conditions, which are sufficiently strong to continue to provide a reinforcing effect in the matrix. It is preferred that they comprise phenolic based fibres. Advantageously both weft and warp threads comprise the same fibres, although hybrid fabrics in which weft and warp threads comprise different fibres may also be suitable. Preferably the fabric is provided with a selvedge, as it is woven, which may be discarded after the fabric has been incorporated into the matrix.

The polymeric matrix may be selected from any of the materials used in the art for protective ablative shields. It is preferred that the polymer matrix is an elastomer and preferably is based upon a terpolymer of ethylene, propylene and a non-conjugated diene, for example cyclopentadiene.

Ablative materials according to the first aspect of the present invention may be used as protective shields for primary structures for which protection from high temperature environments is necessary in order to permit the primary structure to fulfil its function, for example, protective liners for solid propellent rocket motors.

Solid propellent rocket motors burn at high temperatures, sufficient to cause damage to or failure of the rocket motor casing by burning through it. It is therefore necessary to line the internal surface of the motor casing with some form of thermal insulation which is commonly an ablative material. The liner of ablative material separates the propellent charg from the motor casing. As the motor is fired the propellent burns rapidly at a high temperature which chars the liner and by sacrificial loss of the liner material, ie the process of ablation, the liner protects the motor casing from thermal damage.

According to a second aspect of the present invention a rocket motor comprises (a) a casing, (b) a protective liner comprising an ablative material according to the first aspect which is applied to internal surfaces f the casing and (c) a s lid propellent charge, the layer of reinforcing fabric of the ablative material being orientated to lie essentially parallel to the casing, the first surface of the fabric being located adjacent to the propellent and the surface containing the anchor means being directed towards the adjacent part of the casing. Preferably the surface containing the anchor means is essentially parallel to the adjacent part of the casing so that th anchor means point towards that part of the casing.

Conventional reinforced protective liners ar ef-fectively reinforced randomly or in two dimensions only, ie parallel with the rocket motor casing. The purpose of the reinforcement is to slow down the rate of erosion of the liner. However as the char advances towards the casing it eventually travels beyond the reinforcement and having done so, the reinforcement ceases to be effective and the liner tends to delaminate and spall causing pieces of char containing reinforcement to break away from the liner. Therefore conventional reinforced protective liners may incorporate several layers of reinforcement in order that the liner does not erode too rapidly. This inevitably leads to thicker liners than are desirable with a consequent undesirable increase in weight.

These undesirable features of conventional motor casing liners are overcome in an embodiment of the present invention by the incorporation of loops in the reinforcing fabric which hold the reinforcing fabric layer in place. As the char travels through the liner towards the motor casing the tendency of the char to break away from the uncharred material is considerably reduced by virtue of the loops which effectively anchor the char in place. Because the reinforcing fabric layer is held in place by the loops it is possible to use thinner and consequently lighter liners than conventional rocket motor casing liners.

An embodiment of the present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a section of a reinforcing fabric, and

Figure 2 is a cross-section through part of a rocket motor incorporating a liner which includes the fabric as shown in Figure 1.

In Figure 1 a reinforcing fabric 1 comprises a series of regularly alternating warp threads 2 and 3 which are interwoven with a series of weft threads 5 in a plain weave pattern with a weft to warp ratio of 1:1. The warp threads 3 are provided with loops 4 at regularly spaced intervals along their length. The warp threads 2 are unlooped. The fabric 1 is provided with a selvedge 6.

In Figure 2, a rocket motor has a casing 9 a propellent charge 11 and a liner 7 located between the casing 9 and the propellent charge 11. The liner 7 comprises an elastomeric matrix 8 in which is embedded reinforcing fabric 1 which is a fabric as shown in Figure 1. The fabric 1 is orientated so that the surface containing the loops 4 faces towards the casing 9. The unlooped surface of the fabric 1 labelled 10 in Figure 2 is located adjacent to the propellent 11 and parallel to the adjacent part of the casing 9.

An xample of a liner as shown in Figure 2 incorporating fabric as sh wn in Figure 1 was made as follows:

A reinforcing fabric was woven in a plain weave with a weft to warp ratio of 1:1 and with about 9 to 11 threads per inch (3 to 5 threads per cm) incorporating loops in the warp at intervals of 1.3 cm by a conventional weaving process using Kynol (trade name) threads. The woven fabric was placed in a mould and suitable curing system and various ablative additives of the type commonly used in the art, dissolved in toluen solvent, was coated onto the fabric. The solvent was allowed to evaporate before the process was repeated. After ten coats of the solution had been applied and all the solvent had been allowed to evaporate the resulting composite sheet was cold pressed to a thickness of about 2 mm.

On a subsequent firing test the liner was found to erode by 0.4 mm, which compares favourably with 1.3 mm of erosion typically experienced with conventional liners. The liner had a specific gravity of about 1.1 compared to a range of 1.4 to 1.8 in conventional liners.

CLAIMS

1. An ablative material including (a) a layer of woven reinforcing fabric having a first surface and a second surface, the second surface having projecting therefrom anchor means associated with the fabric layer and (b) a polymeric matrix, the fabric layer and the anchor means being embedded within the matrix.

2. An ablative material as claimed in claim 1 and wherein the anchor means extends into the polymeric matrix and projects essentially perpendicularly from the second surface of the fabric.

3. An ablative material as claimed in claim 1 or claim 2 and wherein the anchor means is in the form of short discontinuous or continuous threads which stand proud of the second surface of the fabric, the extent by which they project from the surface approximately corresponding to the required thickness of the ablative material.

4. An ablative material as claimed in any one preceding claim and wherein the reinforcing fabric is a loosely woven plain weave with a weft to warp ratio of 1:1 and about 3-5 threads per cm.

5. An ablative material as claimed in any one preceding claim and wherein the anchor means has been incorporated in the fabric during the weaving process used for making the fabric.

6. An ablative material as claimed in any one preceding claim and wherein the anchor means is in the form of tufts or loops of threads.

7. An ablative material as claimed in claim 6 and wherein the anchor means is in the form of the loops of threads which are provided in the warp.

8. An ablative material as claimed in claim 7 and wherein the loops are provided in alternate warp threads.

9. An ablative material as claimed in claim 7 or claim 8 and wherein the lo ps are arranged at random or in a specific pattern in the fabric.

10. An ablative material as claimed in claim 7 or claim 8 and wherein the loops are arranged in rows across the weft.

11. An ablative material as claimed in claim 10 and wherein the spacing between each row of loops is between about 7.5 mm and about 15.5 mm.

12. An ablative material as claimed in claim 11 and wherein the spacing between each row of loops

preceding claim and wherein the fabric is provid d with a selvedge, which may be discarded after the fabric has been incorporated in the polymer matrix.

14. An ablative material as claimed in any on preceding claim and wherein the fabric comprises threads which are sufficiently flexible to allow the formation of loops without cracking or breaking either during formation of the loops or subsequently.

15. An ablative material as claimed in any one preceding claim and wherein the threads neither soften nor melt at the temperatures to which the ablative material is expected to be exposed.

16. An ablative material as claimed in claim 15 and wherein the threads comprise phenolic based fibres.

17. An ablative material as claimed in claim 15 and wherein the threads comprise aramid fibres or carbon fibres.

18. An ablative material as claimed in any one preceding claim and wherein the weft and warp threads comprise the same type of fibre.

19. An ablative material as claimed in claim 1 and wherein the polymer matrix is an elastomer.

20. An ablative material as claimed in claim 19 and wherein the polymer matrix is based on a terpolymer of ethylene, propylene and a non-conjugated diene.

21. An ablative material as claimed in claim 20 and wherein the non-conjugated diene is cyclopentadiene.

22. An ablative material as claimed in any one preceding claim and wherein the ablative material is used as a protective shield for a primary structure for which protection from high temperature environments is necessary in order to permit the primary structure to fulfil its function.

23. A rocket motor including (a) a casing, (b) a protective liner comprising an ablative material as claimed in any one of claims 1 to 21 applied to internal surfaces of the casing and (c) a solid propellent charge, the layer of reinforcing fabric of the ablative material being orientated to lie essentially parallel to the casing, the first surface of the fabric being located adjacent to the propellent and the surface containing the anchor means being directed towards the adjacent part of the casing.

24. A rocket motor as claimed in claim 23 and wherein the surface containing the anchor means is essentially parallel to the adjacent part of the casing so that the anchor means point towards that part of the casing.

25. An ablative material as claimed in any one of claims 1 to 21 and substantially as hereinbefore described with r ference t Figure 1.

26. A rocket motor as claimed in claim 23 or 24 and having a construction substantially as hereinbefore described with reference to Figure 2.

Amendments to the claims have been filed, and have the following effect:-

(a) Claims 1-26 above have been deleted or textually amended.

(b) New r textually amended claims have been filed as follows:-

1. An ablative material having a first surfac and a second surface including a layer of w ven reinforcing fabric embedded in a polymeric matrix, the layer of reinforcing fabric having a first surface and a second surface, the second surface having projecting essentially perpendicularly therefrom loops of thread associated with the fabric, the first surface of the fabric layer being adjacent to the first surface of the ablative material and the loops projecting towards the second surface of the ablative material, the extent by which the loops project from the second surface of the fabric being such that the looped part of each loop is adjacent to the second surface of the ablative material, the loops being arranged in the fabric so as to anchor the fabric in the polymeric matrix, particularly during ablation occuring in the ablative material from the first surface of the material towards the second surface of the material, thereby reducing spalling of the material.

2. An ablative material as claimed in claim 1 and wherein the reinforcing fabric is a loosely woven plain weave with a weft to warp ratio of 1:1 and about 3-5 threads per cm.

3. An ablative material as claimed in claim 1 or claim 2 and wherein the loops are provided in alternate warp threads.

4. An ablative material as claimed in claim 3 and wherein the loops are arranged at random in the fabric.

5. An ablative material as claimed in claim 3 and wherein the loops are arranged in rows across the weft.

6. An ablative material as claimed in claim 5 and wherein the spacing between each row of loops is between about 7.5 mm and about 15.5 mm.

7. An ablative material as claimed in claim 6 and wherein the spacing between each row of loops is about 13 mm.

8. An ablative material as claimed in any one preceding claim and wherein the fabric is provided with a selvedge, which may be discarded after the fabric has been embedded in the polymeric matrix.

9. An ablative material as claimed in anyone preceding claim and wherein the fabric comprises threads which are sufficiently flexible to allow the formation of loops without cracking or breaking either during formation of the loops or subsequently.

10. An ablative material as claimed in any one preceding claim and wherein the threads neither soften nor melt at the temperatures to which the ablative material is expected to be exposed.

11. An ablative material as claimed in claim 10 and wherein the threads comprise phenolic based fibres.

12. An ablative material as claimed in claim 10 and wherein the threads comprise aramid fibres or carbon fibres.

13. An ablative material as claimed in any one preceding claim and wherein the weft and warp threads comprise the same type of fibre.

14. An ablative material as claimed in claim 1 and wherein the polymer matrix is an elastomer.

15. An ablative material as claimed in claim 14 and wherein the polymer matrix is based on a ter-

polymer of ethylene, propylene and a non-conjugated diene.

16. An ablative material as claimed in claim 15 and wherein the non-conjugated diene is cyclopentadiene.

17. An ablative material as claimed in any one preceding claim and wherein the ablative material is used as a protective shield for a primary structure for which protection from high temperature environments is necessary in order to permit the primary structure to fulfil its function.

18. A rocket motor including (a) a casing, (b) a protective liner comprising an ablative material as claimed in any one of claims 1 to 16 applied to internal surfaces of the casing and (c) a solid propellent charge, the layer of reinforcing fabric of the ablative material being orientated to lie essentially parallel to the casing, the first surface of the fabric being located adjacent to the propellent and the surface containing the anchor means being directed towards the adjacent part of the casing.

19. A rocket motor as claimed in claim 18 and wherein the surface containing the loops is essentially parallel to the adjacent part of the casing so that the loops point towards that part of the casing.

20. An ablative material as claimed in any one of claims 1 to 16 and substantially as hereinbefore described with reference to Figure 1.

21. A rocket motor as claimed in claim 18 or 19 and having a construction substantially as hereinbefore described with reference to Figure 2.

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